CHAPTER 7

ELECTRICAL EQUIPMENT

INTRODUCTION

As a Construction Electrician, you will encounter many pieces of electrical equipment and many appliances. A solid background in electrical theory and standards and a working knowledge of the components and of the machines themselves will allow you to install, maintain, troubleshoot, and repair a wide variety of equipment and appliances.

In one way or another, all machines use the same technologies. The differences are in the complexity of their operation and the tasks they perform. This chapter will not cover specific pieces of equipment or appliances but will concentrate on electrical components, motors, controllers, and circuitry that are common to most equipment and appliances.

In this chapter you will find many references to articles, parts, and sections of the National Electrical Code® (NEC®). You should have an NEC® book on hand while reading this chapter. The chapter text is written in general terms. Many of the exceptions given in the NEC® are not included. Look up the sections when they are referenced. The NEC® can be quite confusing, so **read the articles** closely and pay special attention to the notes and exceptions.

MOTOR-BRANCH CIRCUITS

A motor-branch circuit is a wiring system extending beyond the final automatic overload protective device. Thermal cutouts or motor overload devices are not branch-circuit protection. These are supplementary overcurrent protection. The branch circuit represents the last step in the transfer of power from the service or source of energy to utilization devices.

MOTOR-BRANCH-CIRCUIT SHORT-CIRCUIT AND GROUND-FAULT PROTECTION (NEC® 430, PART D)

The Code requires that branch-circuit protection for motor circuits must protect the circuit conductors, the control apparatus, and the motor itself against overcurrent caused by short circuits or grounds (sections 430-51 through 430-58). Fuses or circuit breakers are the most common protectors used as branch-circuit protective devices. These protective devices must be able to carry the starting current of the motor. To carry this current, they may be rated 300 or 400 percent of the running current of the motor, depending on the size and type of motor.

Motor controllers provide motor protection against all ordinary overloads but are not intended to open during short circuits.

Motor-branch circuits are commonly laid out in a number of ways. Figures 7-1 through 7-3 show three motor-branch circuits and how the circuit protection is used in various types of layouts.

As mentioned before, the motor-branch-circuit short-circuit and ground-fault protective device must be capable of carrying the starting current of the motor. For motor circuits of 600 volts or less, a protective device is permitted that has a rating or setting that does not exceed the values given in table 430-152 of the Code. An instantaneous-trip circuit breaker (without time delay) may be used ONLY if it is adjustable and is part of a listed combination controller, having motor overload and also short-circuit and ground-fault protection in each conductor.

When values for branch-circuit protective devices, as shown in the NEC®, table 430-152, do not correspond to the standard sizes or ratings of fuses, nonadjustable circuit breakers, or thermal protective devices, you may use the next higher size, rating, or setting.

The National Electrical Manufacturer's Association (NEMA) has adopted a standard of identifying code letters that may be marked by the manufacturers on motor nameplates to indicate the motor kilovoltampere input with a locked rotor. These code letters, with their classification, are given in the *NEC®*, table 430-7(b). In determining the starting current to use for circuit calculations, use values from table 430-7(b). Exceptions to the above are given in table 430-52.

When maximum branch-circuit protective device ratings are shown in the manufacturer's overload-relay table for use with a motor controller or are marked on

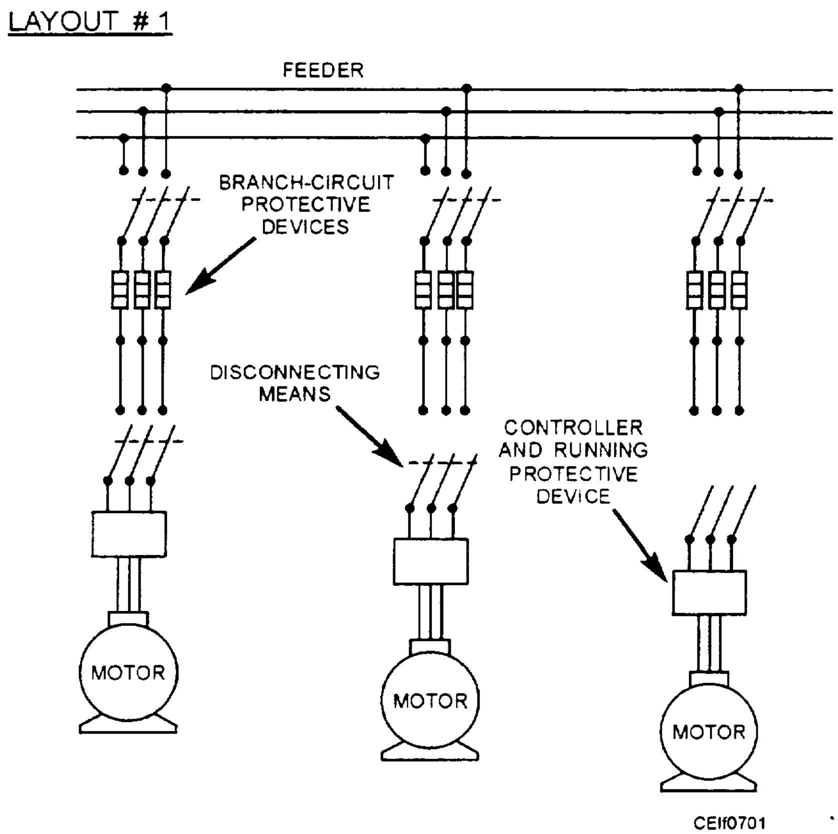

Figure 7-1.—Branch-circuit layout #1.

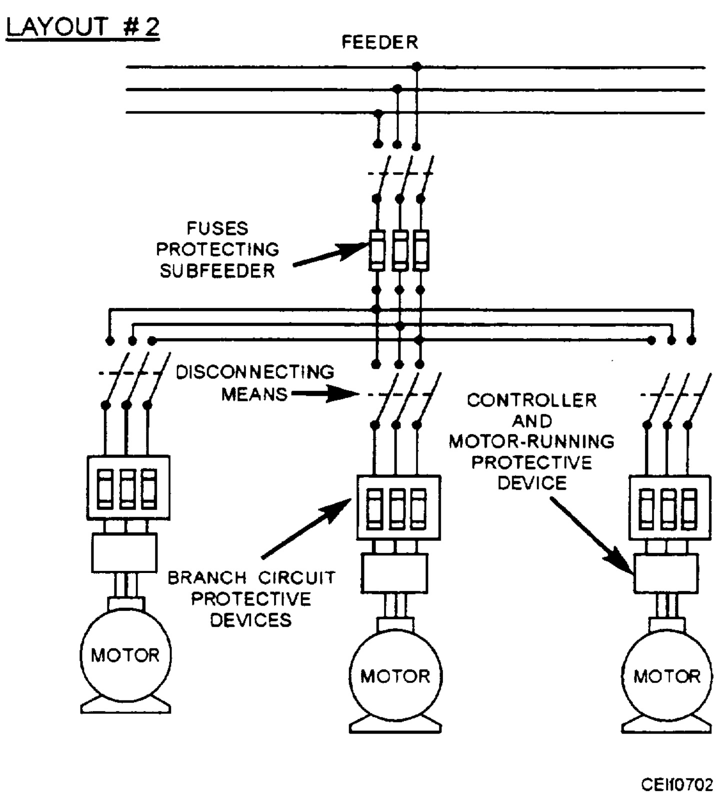

Figure 7-2.—Branch-circuit layout #2.

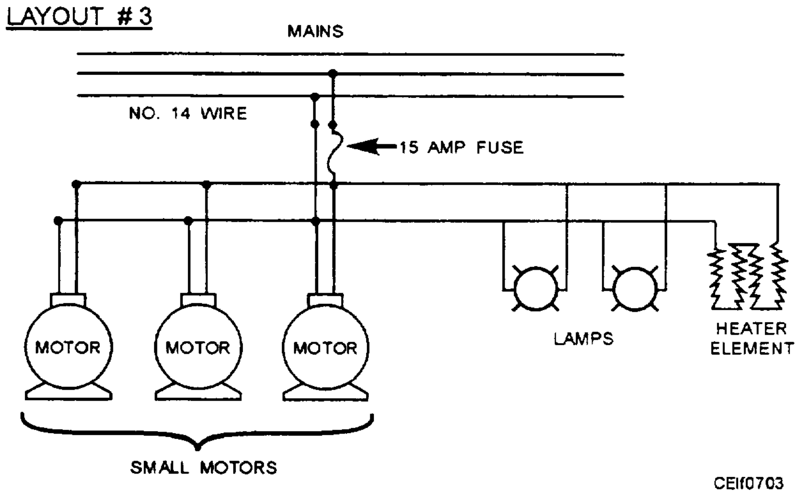

Figure 7-3.—Branch-circuit layout #3.

equipment, you may not exceed them even if higher values are indicated in table 430-152 of the NEC®; however, you may use branch-circuit protective devices of smaller sizes. If you use a branch-circuit device that is smaller, you only need to be sure that it has sufficient time delay to permit the motor-starting current to flow without opening the circuit.

Often it is not convenient or practicable to locate the branch-circuit short-circuit and ground-fault protective device directly at the point where the branch-circuit wires are connected to the mains. In such cases, the size of the branch-circuit wires between the feeder and the protective device must be the same as the mains unless the length of these wires is 25 feet (7.6 meters) or less. When the length of the branch-circuit wires is not greater than 25 feet, the NEC® rules allow the size of these wires to be such that they have an ampacity not less than one third of the ampacity of the mains if they are protected against physical damage.

Figure 7-4 gives you an example of branch-circuit conductor sizing, using the figures found in the *NEC®* tables 430-152 and 430-7(b).

SEVERAL MOTORS OR LOADS ON ONE BRANCH CIRCUIT

You may use a single-branch circuit to supply two or more motors or one or more motors and other loads according to section 430-53 of the Code. Some examples are as follows:

1. Several motors, each not exceeding 1 horsepower, are permitted on a branch circuit protected at not more than 20 amperes at 120 volts or less, or at 600 volts or less protected at not over 15 amperes if all of the following conditions can be met:

- The rating of the branch-circuit short-circuit and ground-fault protective device marked on the controllers is not exceeded.
- The full-load rating of each motor does not exceed 6 amperes.
- Individual overload protection conforms with section 430-32 of the *NEC®*.

2. You may connect two or more motors of any rating to a branch circuit that is protected by a short-circuit and ground-fault protective device selected according to the maximum rating or setting of the smallest motor.

3. You may connect two or more motors of any rating and other loads to one branch circuit if the overload devices and controllers are approved for group installation and if the branch-circuit fuses or circuit-breaker rating is according to section 430-52 of the *NEC®*.

MOTOR FEEDER SHORT-CIRCUIT AND GROUND-FAULT PROTECTION (NEC® 430, PART E)

Overcurrent protection for a feeder to several motors must have a rating or setting not greater than the largest rating or setting of the branch-circuit protective device for any motor of the group plus the sum of the full-load currents of the other motors supplied by the feeder.

Protection for a feeder to both motor loads and a lighting and/or appliance load must be rated on the

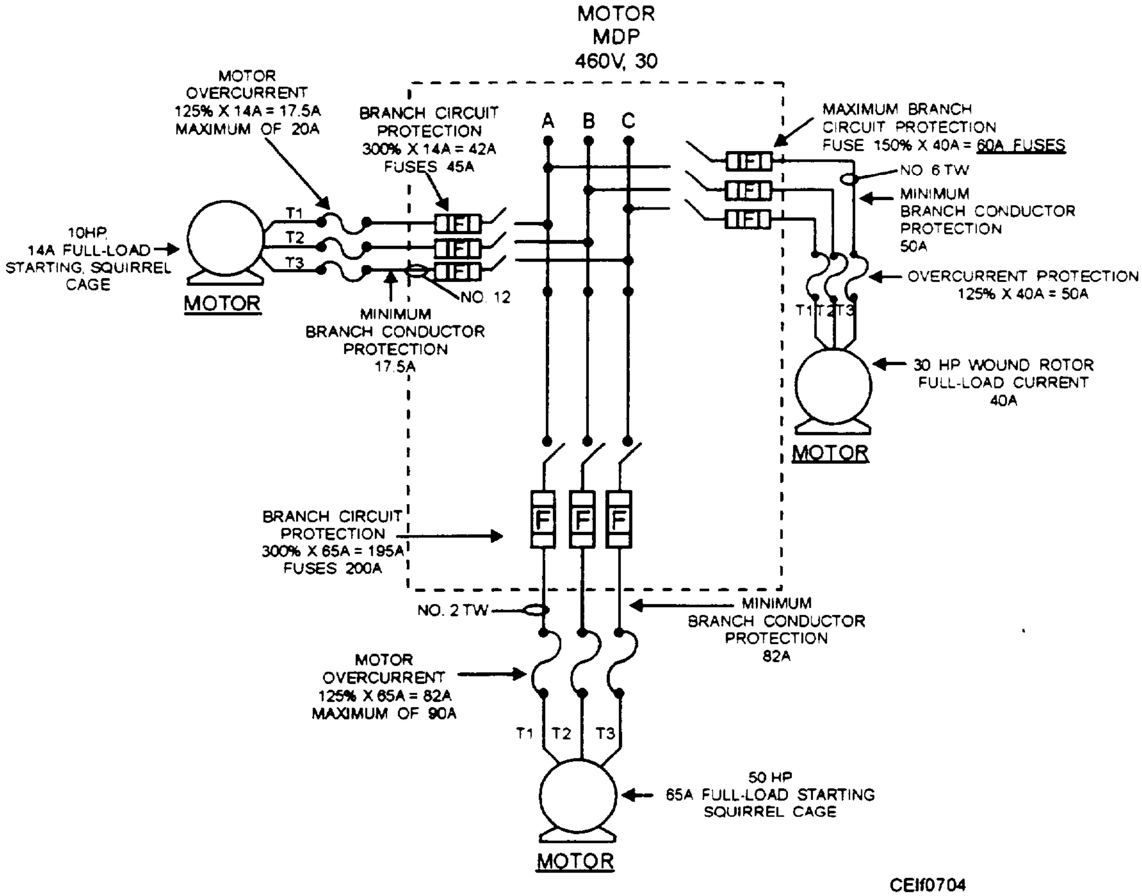

Figure 7-4.—Branch-circuit conductor sizing.

basis of both of these loads. The rating or setting of the overcurrent device must be sufficient to carry the lighting and/or appliance load plus the rating or setting of the motor branch-circuit protective device.

MOTOR CONTROLLER PROTECTION (*NEC® 430*, PART G)

A controller is a device that starts and stops a motor by making and breaking the power current flow to the motor windings. A push-button station, a limit switch, or any other pilot-control device is not considered a controller. Each motor is required to have a suitable controller that can start and stop the motor and perform any other control functions required. A controller must be capable of interrupting the current of the motor under locked-rotor conditions *(NEC®* 430-151) and must have a horsepower rating not lower than the rating of the motor, exceptions as permitted.

Branch-circuit fuses or circuit breakers are considered to be acceptable controller devices under the following conditions:

- For a stationary motor rated at one-eighth horsepower or less that is normally left running and is constructed so that it cannot be damaged by overload or failure to start.
- For a portable motor rated at one-third horsepower or less, the controller may be an attachment plug and receptacle.

The controller may be a general-use switch having an ampere rating at least twice the full-load current rating of a stationary motor rated at 2 horsepower or less and 300 volts or less.

A branch-circuit breaker, rated in amperes only, may be used as a controller. When this circuit breaker is also used for short-circuit and ground-fault and/or overload protection, it will conform to the appropriate provisions of the *NEC®* governing the type of protection afforded. Figure 7-5 will help you to understand controller definitions.

Generally, each motor must have its own individual controller. The exception is for motors rated 600 volts or less; a single controller rated at not less than the sum of the horsepower ratings of all of the

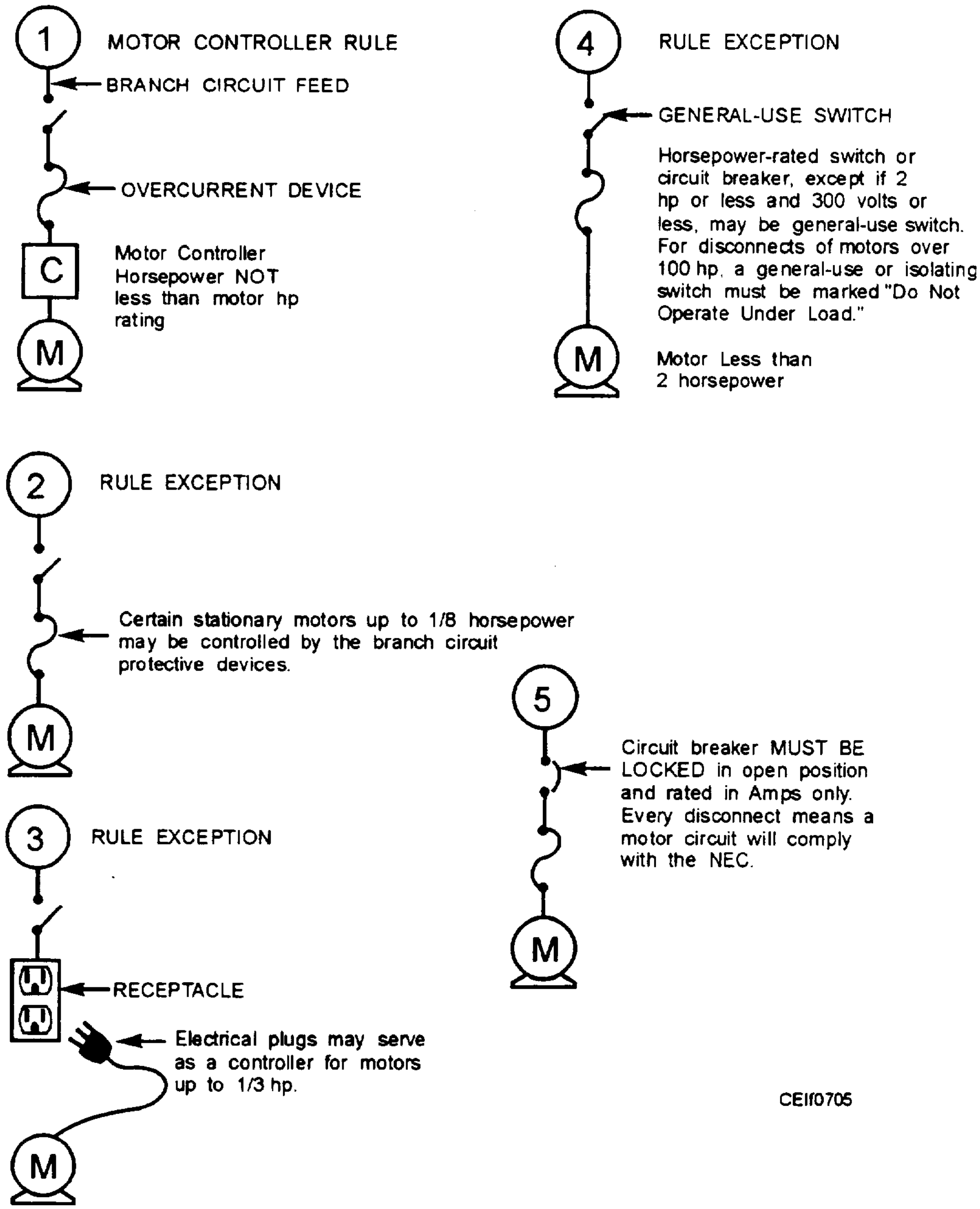

Figure 7-5.—Motor controllers basic rules and exceptions.

motors of the group should be permitted to serve the group of motors under any one of the following conditions:

- Where a number of motors drive several parts of a single machine or a piece of apparatus, such as metalworking and woodworking machines, cranes, hoists, and similar apparatus.
- Where a group of motors is under the protection of one overcurrent device, as permitted in *NEC*® section 430-53(a).
- Where a group of motors is located in a single room within sight of the controller location. A distance of more than 50 feet (15.3 meters) is considered equivalent to being out of sight.

DISCONNECTING MEANS, MOTORS, AND CONTROLLERS (NEC® 430, PART H)

Each motor, along with its controller or magnetic starter, must have some form of approved manual disconnecting means, rated in horsepower, or a circuit breaker. This disconnecting means, when in the OPEN position, must disconnect both the controller and the motor from all ungrounded supply conductors. It must plainly indicate whether it is in the OPEN or the CLOSED position and may be in the same housing as the controller.

For motor circuits of 600 volts or less, the controller manual disconnecting means must be within sight and not more than 50 feet away from the location of the motor controller. There are two exceptions in the Code rule requiring a disconnect switch to be in sight from the controller:

1. For motor circuits over 600 volts, the controller disconnecting means is permitted to be out of sight from the controller, provided the controller is marked with a warning label giving the location and identification of the disconnecting means, and the disconnecting means can be locked in the OPEN position.

2. On complex machinery using a number of motors, a single common disconnect for a number of controllers may be used. This disconnect may be out of sight from one or all of the controllers if it is adjacent to them.

The Code also stipulates that a manual disconnecting means must be within sight and not more than 50 feet from the motor location and the driven machinery. The exception to this rule is that the disconnecting means may be out of sight if it can be locked in the OPEN position. See figure 7-5 for other exceptions and basic rules.

The *NEC*® rules allow a single switch to be the disconnecting means of a group of motors under 600 volts. Also, manual switches or circuit breakers rated in horsepower can be used as a disconnecting means and the controller for many motor circuits.

MOTOR AND BRANCH-CIRCUIT OVERLOAD PROTECTION (NEC® 430, PART C)

Each continuous-duty motor must be protected against excessive overloads under running conditions by some approved protective device. This protective device? except for motors rated at more than 600 volts, may consist of fuses, circuit breakers, or specific overload devices. Overload protection will protect the branch circuit, the motor, and the motor control apparatus against excessive heating caused by motor overloads. Overload protection does not include faults caused by shorts or grounds.

Each continuous-duty motor rated at more than 1 horsepower must be protected against overload by one of the following means:

1. A separate overload device that is responsive to motor current. This device is required to be rated or selected to trip at no more than the following percentage of the motor nameplate full-load current rating:

MOTOR	PERCENT
Motors with a marked service factor not less than 1.15	125
Motor with a marked temperature rise not over 40°C	125
All other motors	115

For a multispeed motor, each winding connection must be considered separately. Modification of these values is permitted. See section 430-34.

2. A thermal, protector, integral with the motor, is approved for use with the motor that it protects on the basis that it will prevent dangerous overheating of the motor caused by overload and failure to start. The percentages of motor full-load trip current are given in section 430-32 (a-2).

3. A protective device. integral with the motor, that will protect the motor against damage caused by failure to start is permitted if the motor is part of an approved assembly that does not normally subject the motor to overloads.

Nonportable, automatically started motors of 1 horsepower or less must be protected against running overload current in the same manner as motors of over 1 horsepower, as noted in section 430-32 (c).

Motors of 1 horsepower or less that are manually started, within sight of the controller location and not permanently installed are considered protected by the branch-circuit protective device.

FUSES FOR MOTOR-OVERLOAD PROTECTION (NEC® 430, PART C)

If regular fuses are used for the overload protection of a motor, they must be shunted during the starting period since a regular fuse having a rating of 125 percent of the motor full-load current would be blown by the starting current. Many dc-motor and some wound-rotor-induction-motor installations are exceptions to this rule. Aside from these exceptions, it is not common practice to use regular fuses for the overload protection of motors. Time-delay fuses sometimes can be used satisfactorily for overload protection since those rated at 125 percent of the motor full-load current will not be blown by the starting current. In fact, the manufacturers of these fuses recommend that for ordinary service. fuses of a smaller rating than 125 percent of the motor full-load current be used.

Even time-delay fuses may not be satisfactory unless they are shunted during the starting period because the 125 percent value cannot be exceeded.

OVERLOAD DEVICES OTHER THAN FUSES (NEC® 430, PART C)

The NEC® (table 430-37) indicates the number and location of overload protective devices, such as trip coils, relays, or thermal cutouts. These overload devices are usually part of a magnetic motor controller. Typical devices include thermal bimetallic heaters, resistance or induction heaters, and magnetic relays with adjustable interrupting and/or time-delay settings. Overload devices can have a manual or automatic reset.

THERMALLY PROTECTED MOTORS (NEC® 430, PART C)

Thermally protected motors are equipped with built-in overload protection, mounted directly inside the motor housing or in the junction box on the side. These devices are thermally operated and protected against dangerous overheating caused by overload, failure to start, and high temperatures. The built-in protector usually consists of a bimetallic element connected in series with the motor windings. When heated over a certain temperature, the contacts will open, thereby opening the motor circuit. On some types, the contacts automatically close when cooled, or a reset button must be operated manually to restart the motor.

PROTECTION OF LIVE PARTS (*NEC®* 430, PART K)

The NEC® requires that live parts be protected in a manner judged adequate to the hazard involved. The following rules apply:

1. Exposed live parts of motors and controllers operating at 50 volts or more between terminals must be guarded against accidental contact by enclosure or by location as follows:

   a. By installation in a room or enclosure accessible only to qualified persons

   b. By installation on a suitable balcony, gallery. or platform so elevated and arranged as to exclude unqualified persons

   c. By elevation 8 feet (2.4 meters) or more over the floor

2. If the live parts of motors or controllers, operating at more than 150 volts to ground, are guarded against accidental contact only by location, as specified in paragraph I, and if adjustment or other attendance may be necessary during the operation of the apparatus, suitable insulating mats or platforms must be provided so that the attendant cannot readily touch live parts without standing on the mats or platforms.

EQUIPMENT GROUNDING

An equipment ground refers to connecting the noncurrent-carrying metal parts of the wiring system or equipment to ground. Grounding is done so that the metal parts a person might come into contact with are always at or near ground potential. With this condition, there is less danger that a person touching the equipment will receive a shock.

GROUNDING EQUIPMENT FASTENED IN PLACE OR CONNECTED BY PERMANENT WIRING METHODS (FIXED) (NEC® 250, PART E)

The word *fixed*, as applied to equipment requiring grounding, now applies to equipment fastened in place or connected by permanent wiring, as shown in figure 7-6. That usage is consistently followed in other Code sections also.

The Code requires that all exposed noncurrent-carrying metal parts, such as equipment enclosures, boxes, and cabinets, must be grounded. Equipment must be grounded where supplied by metallic wiring methods; in hazardous locations; where it comes into contact with metal building parts; in wet, nonisolated locations; within reach of a person who is in contact with a grounded surface; and where operated at over 150 volts.

METHODS OF GROUNDING (*NEC®* 250, PART F)

Section 250-51 sets forth basic rules on the effectiveness of grounding. This rule defines the phrase effective grounding path and establishes mandatory requirements on the quality and quantity of conditions in any and every grounding circuit. The three required characteristics of grounding paths are very important for safety:

1. That every grounding path is permanent and continuous. The installer can ensure these conditions by

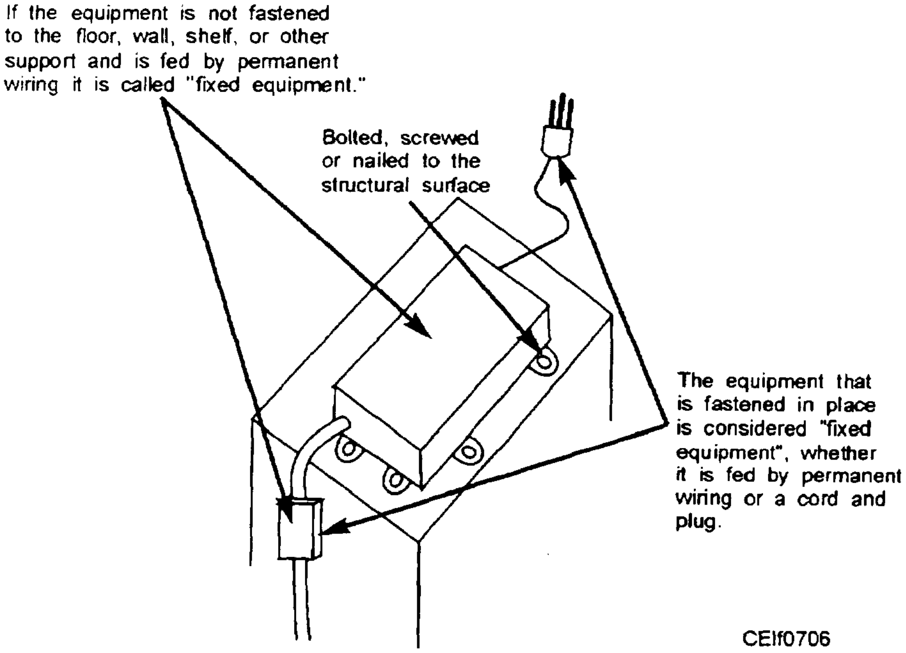

Figure 7-6.—Definition of fixed equipment.

proper mounting, coupling, and terminating of the conductor or raceway intended to serve as the grounding conductor. The installation must be made so that it can be inspected by an electrical inspector, the design engineer, or any other authority concerned. A continuity test with a meter, a light, or a bell will assure that the path is "continuous."

2. That every grounding conductor has the capacity to conduct safely any fault current likely to be imposed on it. Refer back to the section of the Code that specifically establishes a minimum required size of grounding conductor.

3. That the path to ground has sufficiently low impedance to limit the voltage to ground and to facilitate the operation of the circuit protective devices in the circuit.

USE OF GROUNDED CIRCUIT CONDUCTOR FOR GROUNDING EQUIPMENT (*NEC*®, SECTION 250-61)

Part (a) of *NEC*®, section 250-61, permits the grounded conductor (usually the neutral) of a circuit to be used to ground metal equipment enclosures and raceways on the **supply side** of the service disconnect. Figure 7-7 shows such applications. At **(A),** the grounded service neutral is bonded to the meter housing by means of the bonded neutral terminal lug in the socket. The housing is thereby grounded by this connection to the grounded neutral, which itself is grounded at the service equipment as well as at the utility transformer secondary supplying the service. At **(B),** the service equipment enclosure is grounded by connection (bonding) to the grounded neutral, which itself is grounded at the meter socket and at the supply transformer. These same types of grounding connections may be made for cabinets, auxiliary gutters, and other enclosures on the line side of the service entrance disconnect means, including the enclosure for the service disconnect. At **(C),** equipment is grounded to the neutral on the line (supply) side of the first disconnect fed from a step-down transformer (a separately derived system).

Aside from the permission given in the five exceptions to the rule of part(b) of section 250-61, the Code prohibits connection between a grounded neutral and equipment enclosures on the **load side** of the service. So bonding between any system grounded conductor, neutral or phase leg, and equipment enclosures is prohibited on the load side of the service (fig. 7-8). The use of a neutral-to-ground panelboard or other equipment (other than specified in the exceptions) on the load side of service equipment would be extremely hazardous if the neutral became loosened or disconnected. In such cases, any line-to-neutral load would energize all metal components connected to the neutral, creating a dangerous potential for electrocution. Hence such a practice is prohibited. This prohibition is fully described in figure 7-9.

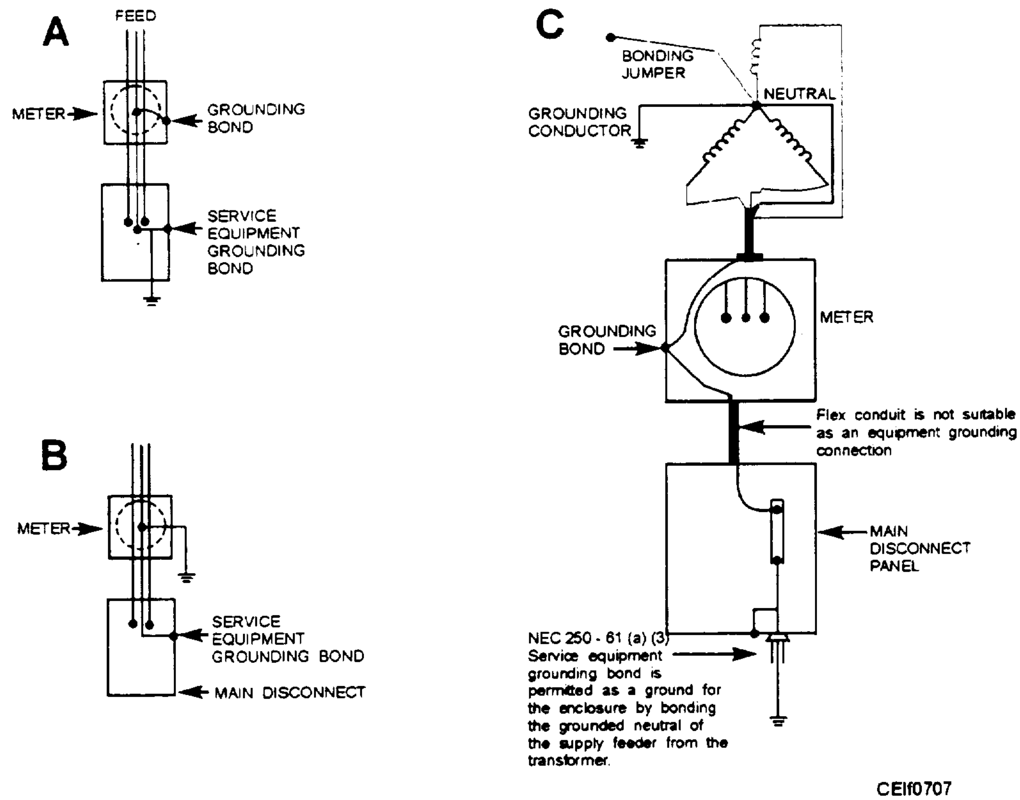

Figure 7-7.—Equipment housing ground connections (line side).

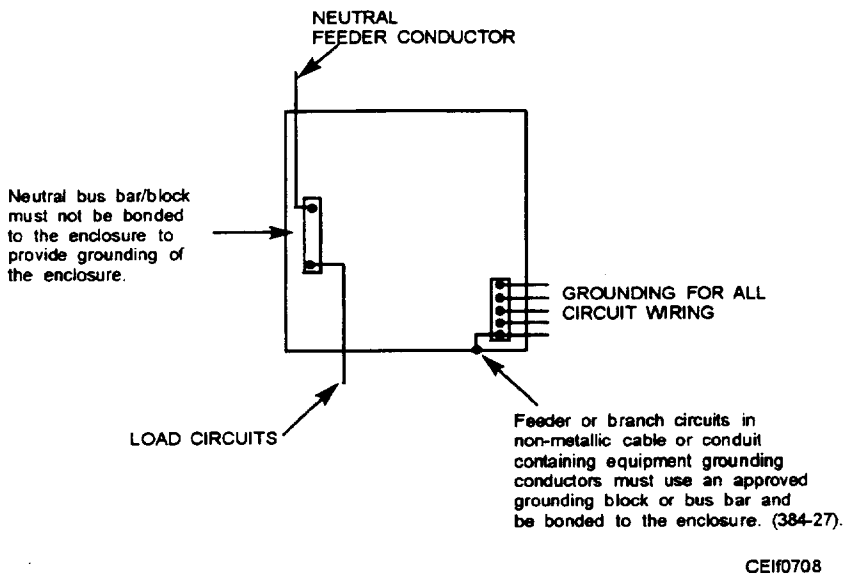

Figure 7-8.—Equipment housing ground connections (load side).

Although this rule of the Code prohibits neutral bonding on the load side of the service, sections 250-50(a) and 250-53(b) clearly require such bonding at the **service entrance.**

The circuit conductors used for equipment grounding must be within the same raceway, cable, or cord or run with the circuit conductors. The conductors may be bare or insulated. The insulated conductors must have a continuous outer finish of green or green with one or more yellow stripes.

When the equipment grounding is to be accomplished by the protective device of the circuit

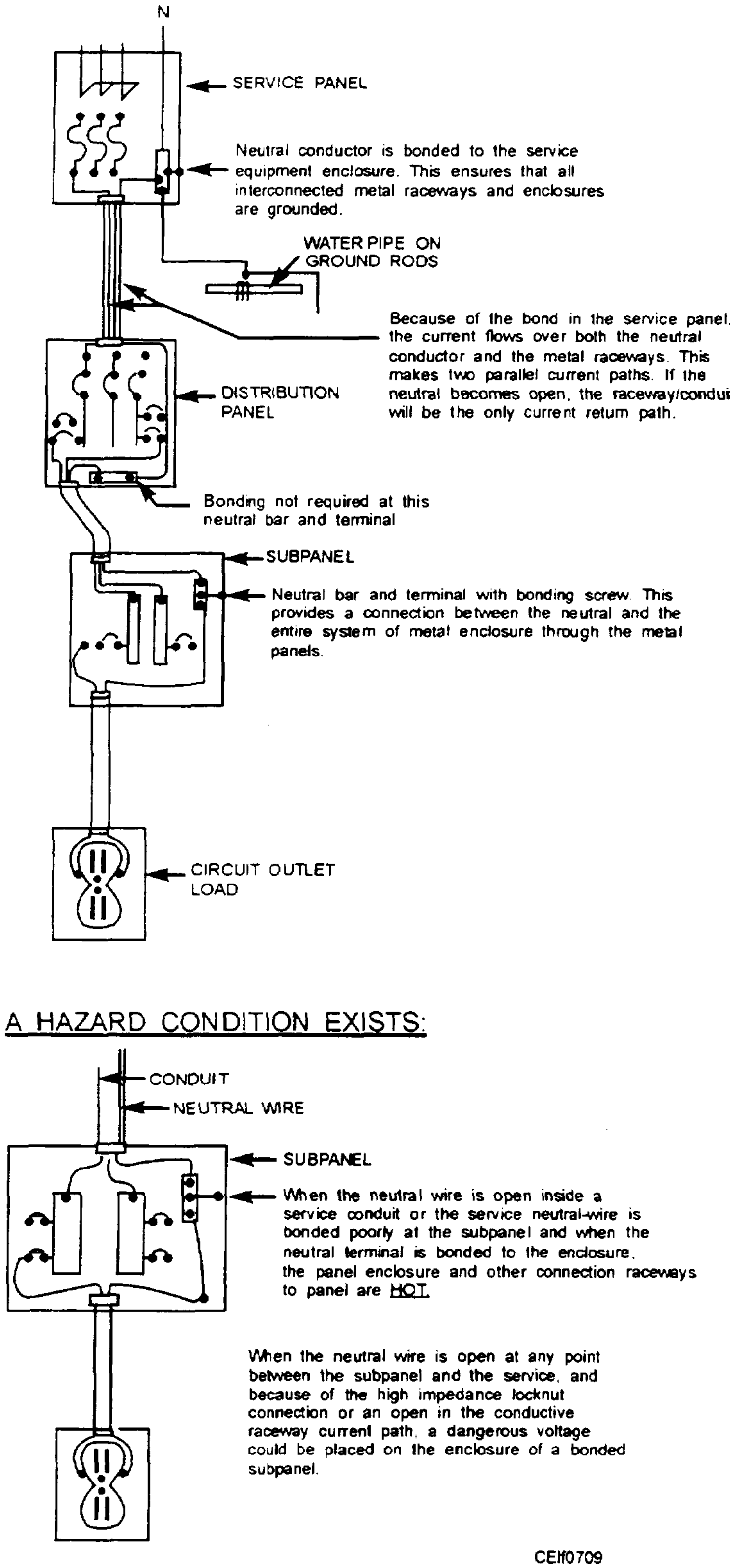

Figure 7-9.—Subpanel bonding hazards.

conductors, it must be rigid metal conduit, intermediate metal conduit, electrical metallic tubing, flexible metal conduit, type AC cable, or the combined metallic sheath and grounding conductors of type MC cable.

Flexible metal conduit is permitted as an equipment grounding conductor if the following conditions are met: the length of the flex does not exceed 6 feet, the circuit conductors within are rated at 20 amperes or less, and the connectors are fittings listed for grounding. If the 6 feet of flex is exceeded, a bonding jumper wire, run inside the flex, must be used.

CONTROL CIRCUITS

The subject of electric control circuits is quite broad. The following text will cover a few of the basic control circuit requirements and controls. For more information, refer to special books devoted to this important phase of motor circuitry. Two such books are *Electric Motor Control* by Walter N. Alerich and *Electric Motor Repair* by Robert Rosenberg and August Hand. These textbooks provide an excellent insight on how to understand, select, and design control circuits.

CONTROL CIRCUITS GENERAL *(NEC®* 430, PART F and ARTICLE 725)

A control circuit is a circuit that exercises control over one or more other circuits. These other circuits controlled by the control circuit may themselves be control circuits, or they may be "load" circuits that carry utilization current to a lighting, heating, power, or signal device. Figure 7-10 clarifies the distinction between control circuits and load circuits.

The elements of a control circuit include all the equipment and devices concerned with the function of the circuit: conductors, raceway, contactor-operating coil, source of energy supply to the circuit, overcurrent protective devices, and all switching devices that govern energization of the operating coil.

Typical control circuits include the operating-coil circuit of magnetic motor starters, magnetic contactors, and relays. Control circuits include wiring between solid-state control devices as well as between magnetically actuated components. Low-voltage relay switching of lighting and power loads also are classified as remote-control wiring.

A control circuit is divided into three classes:

- Class 1 system may operate at any voltage that does not exceed 600 volts. They are, in many cases, merely extensions of light and power systems, and, with a few exceptions, are subject to all the installation rules for light and power systems.

- Class 2 and Class 3 systems are those systems in which the current is limited to certain specified low values. This limiting may be accomplished by fuses or circuit breakers, by transformers that deliver only very small currents, or by other voltages at which the system operates from 5 milliamps or less. All Class 2 and Class 3 circuits must have a power source with the power-limiting characteristics described in NEC®, table 725-31(a). These requirements are in addition to the overcurrent device.

Conductors for any Class 1 control circuit must be protected against overcurrent. Number 14 and larger wires must generally be protected at their ampacities. (Review *NEC®*, table 310-16.) Number 18 and Number 16 control wires must always be protected at 7 and 10 amperes, respectively.

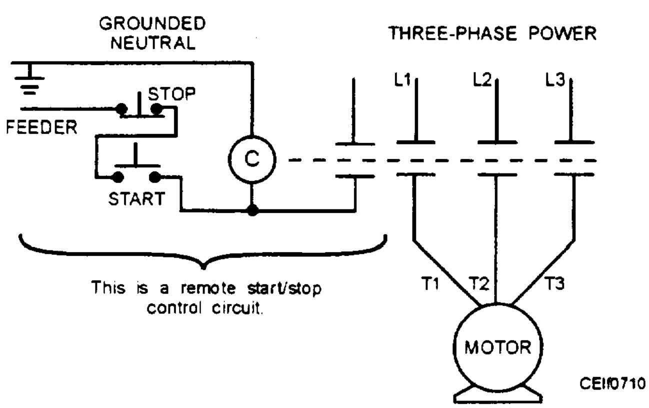

Figure 7-10.—Defining a control circuit.

Any number and any type of Class 1 circuit conductors may be installed in the same conduit, raceway, box, or other enclosure if all conductors are insulated for the maximum voltage at which any of the conductors operates and the wires are functionally associated with each other.

Class 1 circuit wires may be run in raceways by themselves according to the *NEC*®. The number of conductors in a conduit must be determined from tables 1 through 5 in chapter 9 of the *NEC*®*)*.

CONTROL SYMBOLS

In figures 7-11 and 7-12, you see the electrical symbols that conform to the standards established by the National Electrical Manufacturer's Association (NEMA). Where NEMA standards do not exist, American Standards Association (ASA) standards are used; however, not all manufacturers use these established symbols. In spite of the lack of standardization, knowledge of the symbols presented in this unit will give you a firm basis for interpreting variations found in the field.

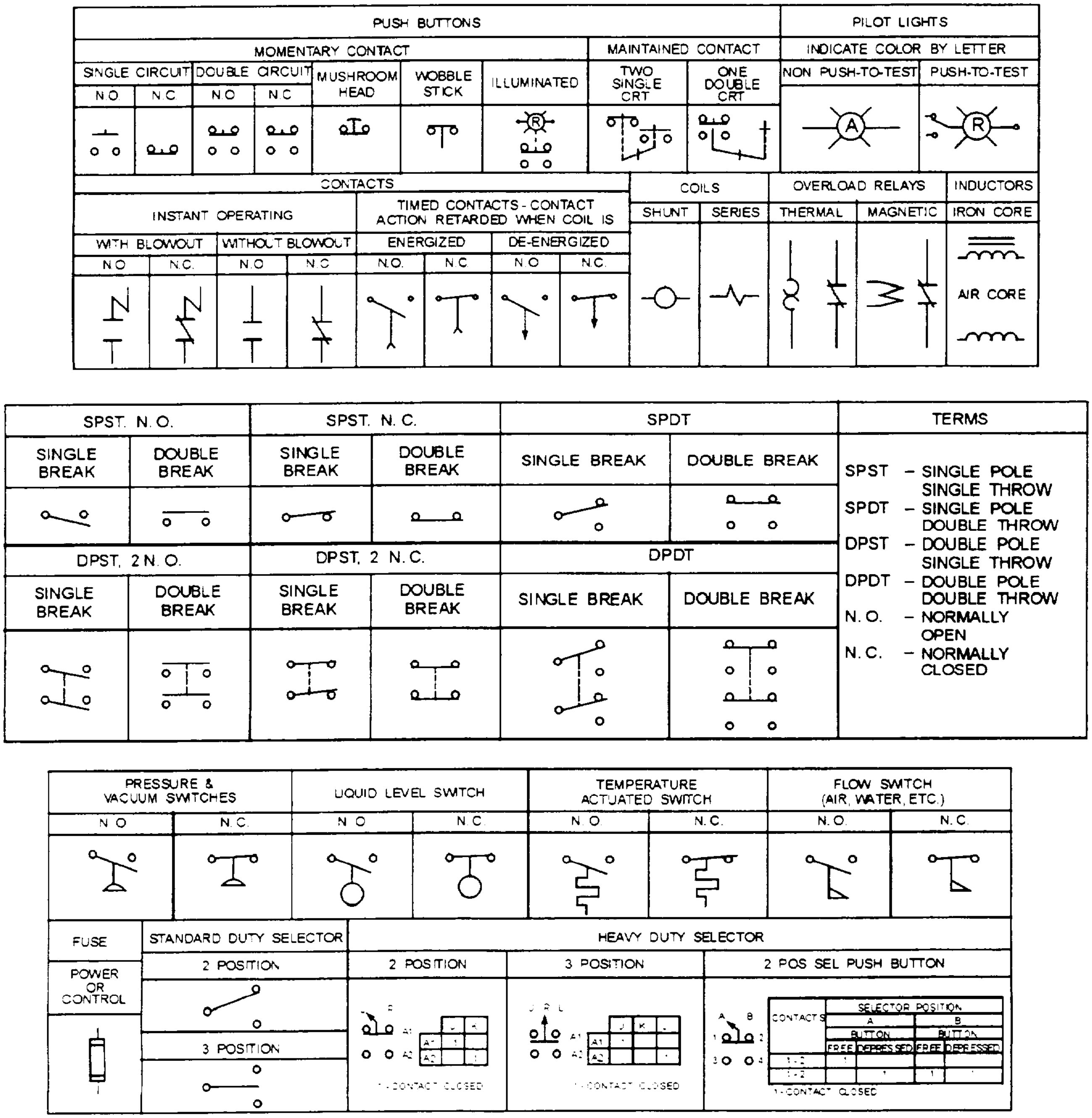

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Figure 7-11.—Standard wiring diagram symbols.

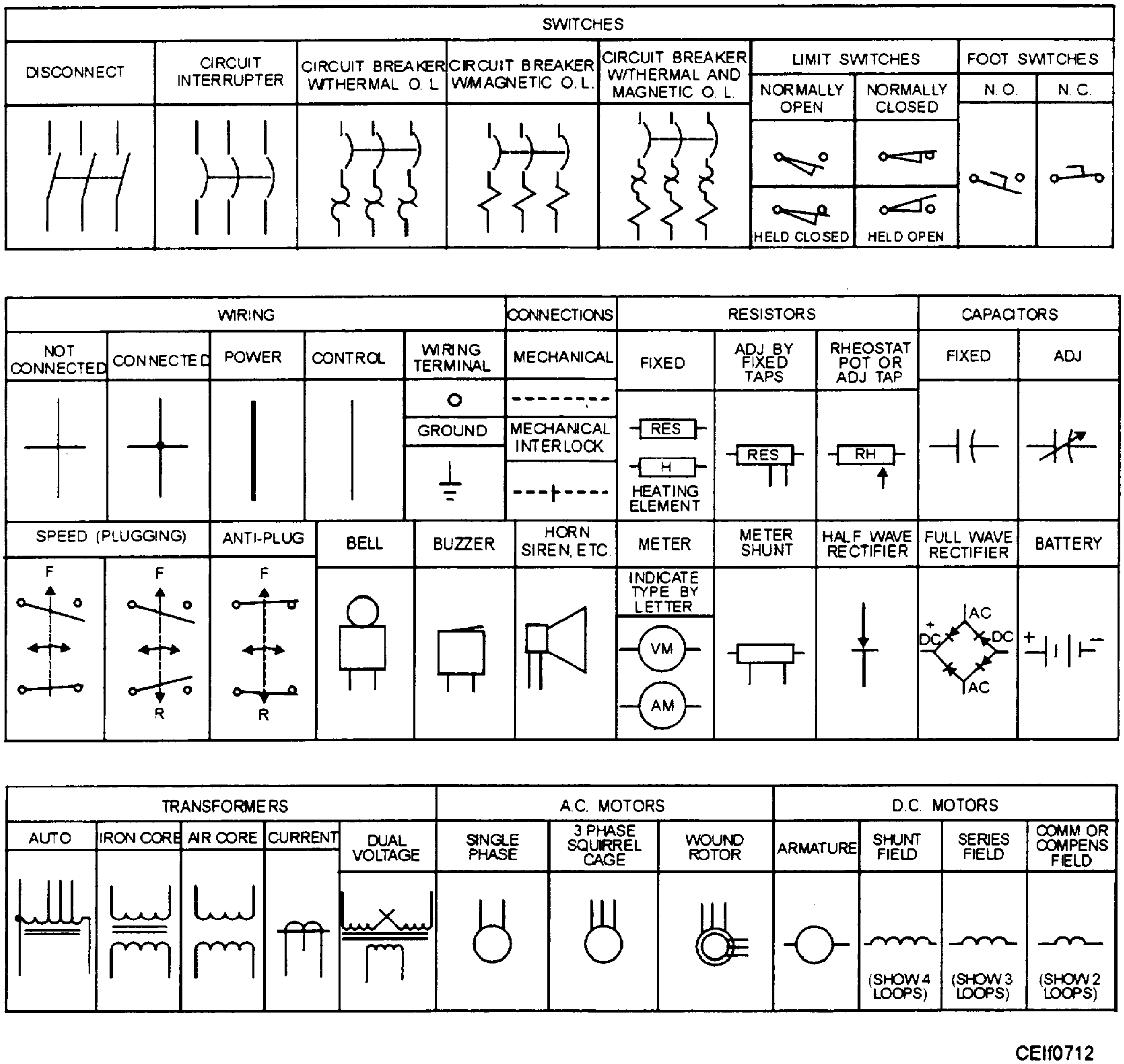

Figure 7-12.—Standard wiring diagram symbol—Continued.

The control-circuit line diagram of figure 7-13 shows the symbol of each device used in the circuit and indicates its function. The push-button station wiring diagram on the right of figure 7-13 represents the physical control station and shows the relative position of each device, the internal wiring, and the connections with the motor starter.

Control and Power Connections

The correct connections and component locations for line and wiring diagrams are shown in table 7-1. Compare the information given in the table with actual line diagrams to develop the ability to interpret the table quickly and use it correctly; for example, refer to figure 7-14 and the three-phase column of table 7-1. Note that the control circuit switching is connected to line 1 **(L1)** and the contactor coil is connected to line 2 **(L2)**

Control Wiring

Control wiring can be very confusing. A single operation of an electrical circuit is usually not complicated; however, a sequence of operations, one depending on the other, in a complex circuit can be

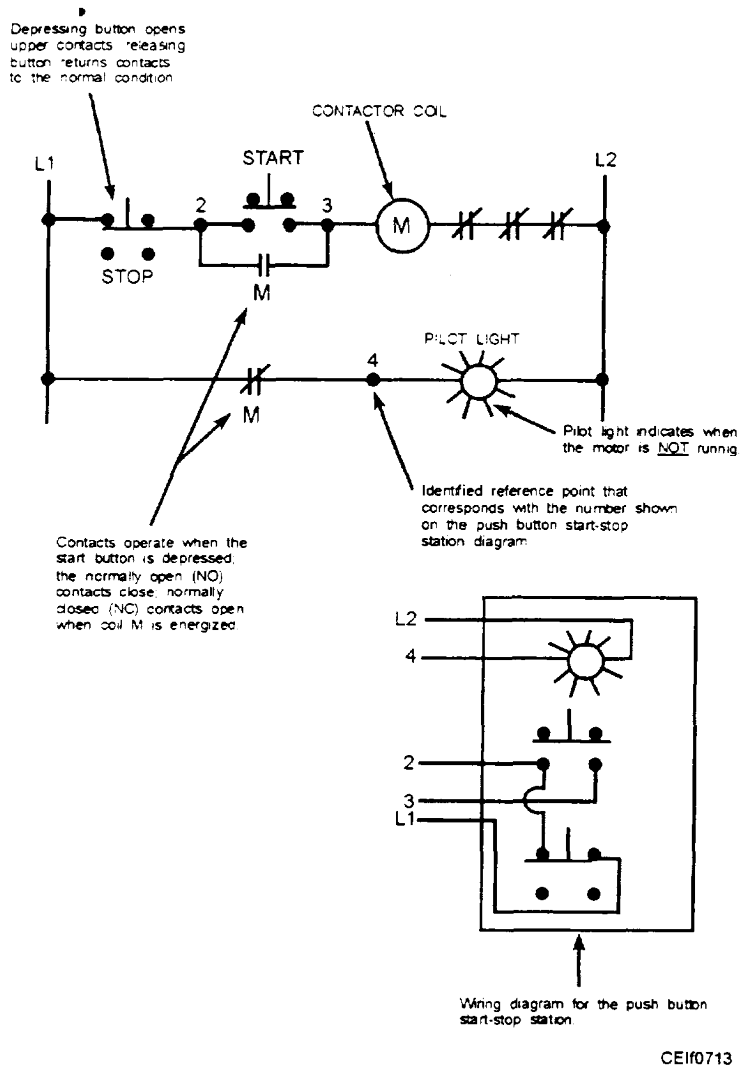

Figure 7-13.—Control circuit components.

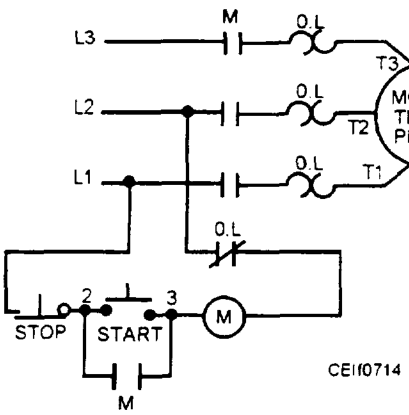

Figure 7-14.—Three-phase motor controller diagram.

difficult to understand. As you already know, most electrical circuits are represented as a wiring diagram or a line diagram. Work through the examples given throughout this chapter. This practice will improve your skills in reading and understanding electrical diagrams. If the diagrams are too complex, break them down to a more elementary diagram. These diagrams are your key to understanding how a machine operates and how to repair it when it breaks.

TWO-WIRE CONTROL.—Two-wire control provides no-voltage release or low-voltage release. Two-wire control of a starter means that the starter drops out when there is a voltage failure and picks up as soon as the voltage returns. In figure 7-15, the pilot device is unaffected by the loss of voltage. Its contact remains closed, ready to carry current as soon as line voltage returns to normal.

The phrases **no-voltage** release and **two-wire control** should indicate to you that an automatic pilot device, such as a limit switch or a float switch, opens and closes the control circuit through a single contact.

Table 7-1.—Power and Control Connections for Across-the-Line Motor Controllers/Starters

	DIRECT CURRENT	SINGLE PHASE	THREE PHASE
Line markings for.	L1 & L2	L1 & L2	L1, L2, & L3
Overload relay heaters in	L1	L1	T1, T2, & T3
Contactor coil connected to	L2	L2	L2
Overload relay contacts in	L2	L2	L2
Control circuits connected to	L1 & L2	L1 & L2	L1 & L2
Control circuit switching connected to.	L1	L1	L1
Reversing interchange lines.	N/A	N/A	L1 & L3
Requiring grounding.	L1 is **always** ungrounded	L1 is **always** ungrounded	L2

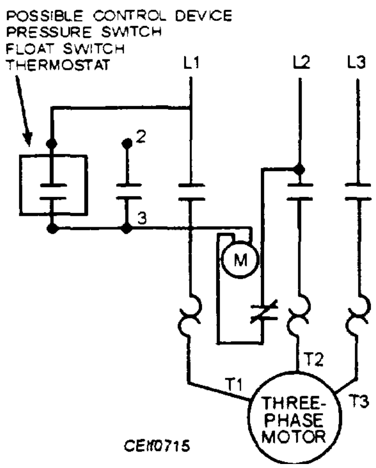

Figure 7-15.—Two-wire control circuit.

THREE-WIRE CONTROL.—The three-wire control involves the use of a maintaining circuit. This method eliminates the need for the operator to press continuously on the push button to keep the coil energized. Refer to the elementary control circuit diagram in figure 7-16. When the START button is pressed, coil M is energized across L1 and L2. This action closes contact M to place a shunt circuit around terminals 2 and 3. the START button. A parallel circuit is formed with one circuit through push-button terminals 2 and 3 and one circuit through contact M. As a result. current will flow through the M coil. If pressure is removed from the START button, terminals 2 and 3 open. The other circuit through contacts M remains closed. supplying current to coil M and maintaining a started-closed position. Such a circuit is called a maintaining circuit: a sealing circuit, or a holding circuit.

The phrases no-voltage protection and three-wire control should indicate to the electrician that the most common means of providing this type of control is a start-stop push-button station.

The main distinction between the two types of control is that in no-voltage release (two-wire control), the coil circuit is maintained through the pilot-switch contacts; in no-voltage protection (three-wire control), the circuit is maintained through a stop contact on the push-button station and an auxiliary (maintaining) contact on the starter.

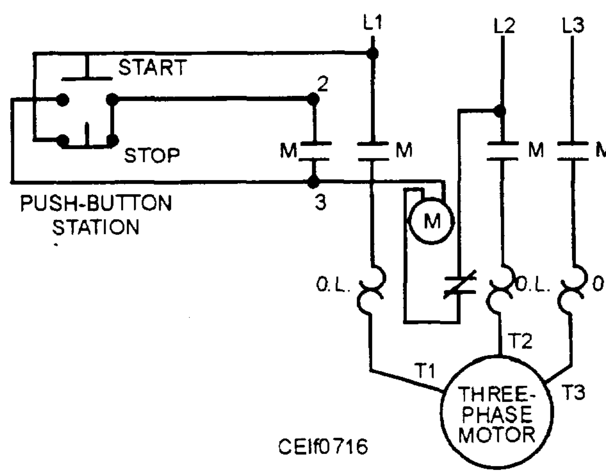

Figure 7-16.—Three-wire control circuit.

LOW-VOLTAGE CONTROL.—Sometimes it is desirable to operate push buttons or other control devices at some voltage lower than the motor voltage. in the control system for such a case. a separate source. such as an isolating transformer or an independent voltage supply, provides the power to the control circuit. This independent voltage is separate from the main power supply for the motor.

One form of separate control is shown in figure 7-17. When the thermostat calls for cooling and the high-low pressure control is activated, the compressor motor starter coil M is energized through the step-down isolating transformer. When coil M is energized, power contacts in the 240-volt circuit close to start the refrigeration compressor motor. Since the control circuit is separated from the power circuit by the isolating control transformer, there is no electrical connection between the two circuits. For this reason, the wire jumper attached to L2 on a starter should be removed for different voltages; however, the overload relay control contact must be included in the separate control wiring.

TROUBLESHOOTING AND TESTING CONTROLLERS

In this section it is assumed that the motor and fuse are in good condition. To make certain that the motor is not at fault, connect a voltmeter at the motor terminals and determine whether voltage is available when the contacts of the controller are closed. If there is no voltage, the trouble probably, lies in the controller.

TROUBLESHOOTING

By using a snap-around type of voltmeter-ohmmeter or individual instruments, you can conduct many of the tests needed to determine opens, shorts, grounds. and continuity in just a short time. You can test malfunctioning circuits for shorted coils; open coils; grounded coils; open resistances; shorted resistances; low voltages; high voltages: excessive amperes; broken, loose, or dirty connections; and many other problems with comparative ease. This testing is true of all motors. as well as starters.

You should follow a systematic procedure when troubleshooting controls.

WARNING

You must exercise extreme caution when testing live components. Always use the one-hand rule to avoid completing the circuit between the live component and a metal sur-face. Always have a second person standing by when working on energized equipment and ensure the person is qualified in CPR. When working on anything that should have the power off, always shut the power off **yourself.** Most disconnects have allowances for a padlock to be used to keep the power from being turned back on. This safety precaution is called “LOCKOUT.” The NAVOSH Manual, OPNAVINST 5 100.23, provides guidance on the Lockout/Tag out program at shore activi-ties according to OSHA regulations. It is extremely important to take this precaution. Controls with voltage over 240 volts should never be energized when you are troubleshooting.

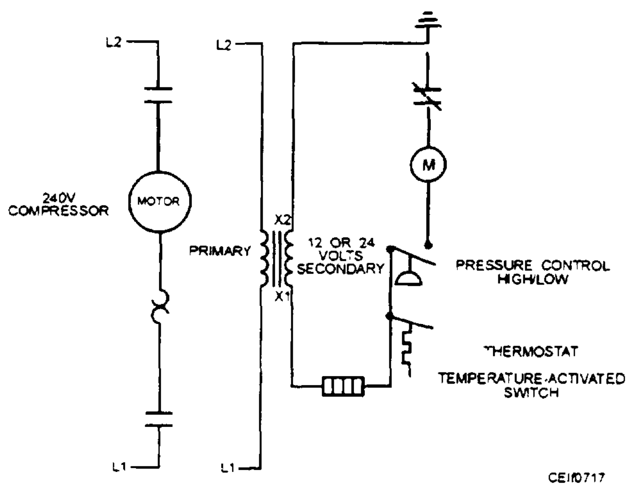

Figure 7-17.—Low-voltage control circuit.

Because there are so many different kinds and makes of controllers, we will outline a genera! procedure for locating the source of trouble.

1. If the motor does not start when the main contacts close, the trouble may be as follows:

a. Open overload heater coil or poor connection.

b. Main contacts not making contact. It is not unusual for one or more contacts to wear to the degree that they will not make when closed. This fault will also occur if the contacts become dirty, gritty, or burned.

c. Broken, loose, or dirty terminal connection.

d. Loose or broken pigtail connection.

e. Open resistance units or open autotransformer.

f. Obstruction of the magnet core, preventing the contacts from closing.

g. Mechanical trouble, such as mechanical interlocks, gummy pivots, and poor spring tension.

2. If the contacts do not close when the START button is pressed, the trouble may be as follows:

a. Open holding coil. This can be tested by connecting a voltmeter across the coil terminals when the START button is pressed. If there is voltage when the START button is pressed but the coil does not become energized, the coil is defective.

b. Dirty START button contacts or poor contact.

c. Open or dirty STOP button contacts. If more than one station is connected to the same controller, each station should be checked. If FORWARD-REVERSE stations are used and they are interlocked, check all contacts.

d. Loose or open terminal connections.

e. Open overload-relay contacts.

f. Low voltage.

g. Shorted coil.

h. Mechanical trouble.

3. If the contacts open when the START button is pressed, the trouble may be as follows:

a. Contacts that do not close completely or are dirty, pitted, or loose.

b. Wrong connection of station to the controller.

4. If a fuse blows when the START button is pressed, the trouble may be as follows:

a. Grounded circuits.

b. Shorted coil.

c. Shorted contacts.

5. If the magnet is noisy in operation, the trouble may be as follows:

a. Broken shaded pole causing chattering.

b. Dirty core face.

6. If the magnet coil is burned or shorted, the trouble may be as follows:

a. . Overvoltage.

b. Excessive current due to a large magnetic gap caused by dirt, grit, or mechanical trouble.

c. Too frequent operation.

TESTING COMPONENT CIRCUITS

The example used here is a control that is operated by a remote switch, such as a float switch. It is assumed that the device being controlled (a three-phrase motor) is in good working order but is not receiving power. Figure 7-18 shows such a circuit.

The first thing you should check is the line voltage. To do this check, remove the cover of the control box and test each line with a voltmeter. You should take the volt readings between L1 and L2, L2 and L3, and then between L3 and L1 . If full voltage is found, you should visually check the power circuit for loose connections. These terminals include L1, L2, L3, T1, T2, and T3. Look for signs of heating at these connections. When a connection becomes loose, the terminal becomes very hot; and the screw, wire, and terminal become discolored or charred. Check all terminals and tighten them if necessary. **You should only do this checking and tightening with the power OFF.**

Next, check the control circuitry within the controller. Do this check by looking at the control circuit shown in figure 7-18. The external controls, the magnetic holding coil, and the normally closed overload contacts are always located between line 1 and line 2. Unless the control has been altered, line 3 is not part of the control circuit. Check also that the externally located controlling switches, such as the

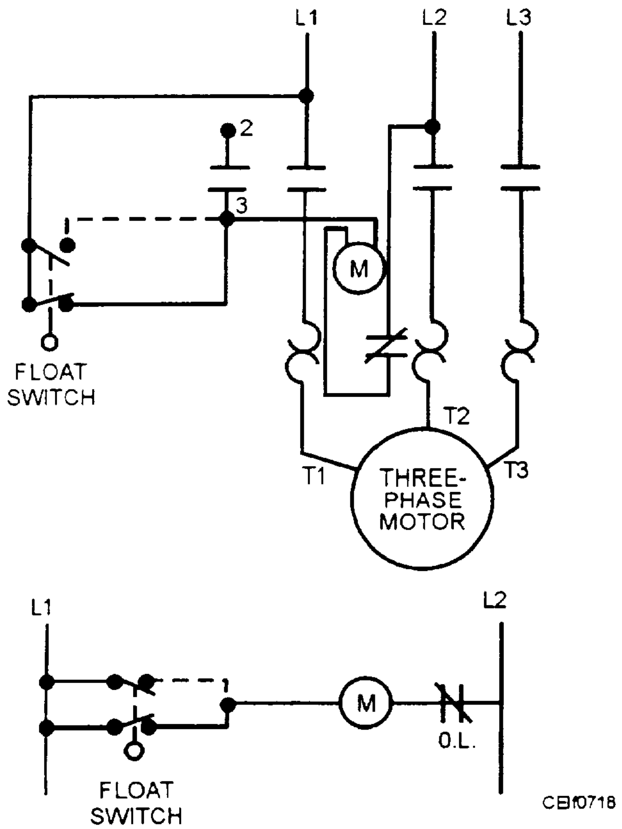

Figure 7-18.—Three-phase starter controlled by a float switch.

push button, the float, the pressure, or the limit switches, are connected between line 1 and the holding coil. The normally closed overload contacts are always located between the holding coil and line 2. A wiring diagram usually can be found in the cover of the controller. Now it has been established that the motor and line voltage are in working order. This checking has narrowed the problem to the control circuit and the chance that some components are open.

You can locate opens in the control circuit with a voltmeter. Connect one lead of the voltmeter to line 1, and touch the other lead to first one terminal or the holding coil and then the other terminal. There should be the same voltage reading that is read between line 1 and line 2. If the control circuit voltage is supplied with a transformer. the voltage read should be that of the transformer output. If there is no voltage on either side of the holding coil, the overload contacts are open. Pushing the RESET button should close the overload contacts. If they do not close after they have had time to cool. they may be defective. In this case. they should be replaced.

If there is a voltage on one terminal of the holding coil but not the other, the coil is open. You must then replace the coil. If there is a voltage on both terminals of the holding coil, the coil and the overload contacts can be assumed to be in working order. To double-check these components, short out line 1 and the terminal marked 3 with a piece of wire. This action will bypass the external control, and then the holding coil should close the contacts. You can use a current-limiting resistor in place of a w-ire. If the control functions, the problem is in the external controlling device.

Solid-state controllers have very complicated circuitry; thus, troubleshooting these units requires a good background in electronics and electric motors. These controllers have repair instructions with them as well as a list of parts that should be stocked for repair purposes. Repairs consist of replacing boards or modules that plug into the circuity.

COMBINATION STARTERS

A combination starter consists of a magnetic starter and disconnect switch mounted in the same enclosure. These starters are supplied with either a fused disconnect switch or a circuit breaker. The fuses (or circuit breaker) provide short-circuit protection by disconnecting the line. A combination starter and circuit breaker will prevent single phasing by simultaneously opening all lines when a fault occurs in any one phase. This type of starter can be quickly reset after the fault has been cleared. Figure 7-19 shows a fused combination starter. Figure 7-20 shows a combination starter and a thermal-magnetic circuit breaker.

PUSH-BUTTON-STATION CONNECTIONS

We will now show you a number of control circuits with various combinations of push-button stations. A!! of these diagrams use one type of magnetic switch, but others can be used. Figure 7-21 shows a magnetic switch that is operated from any of three stations. Figure 7-22 shows a straight-line diagram of the control circuit of three start-stop stations. Figure 7-23 shows the control circuit of two start-stop stations. In these diagrams, the START buttons are connected in parallel, and the STOP buttons are connected in series. These button connections must be done regardless of the number of stations. Note that the maintaining contact is always connected across the START button. All STOP buttons are connected in series with one another and in series with the holding coil, so the motor can be stopped from any position in case of emergency.

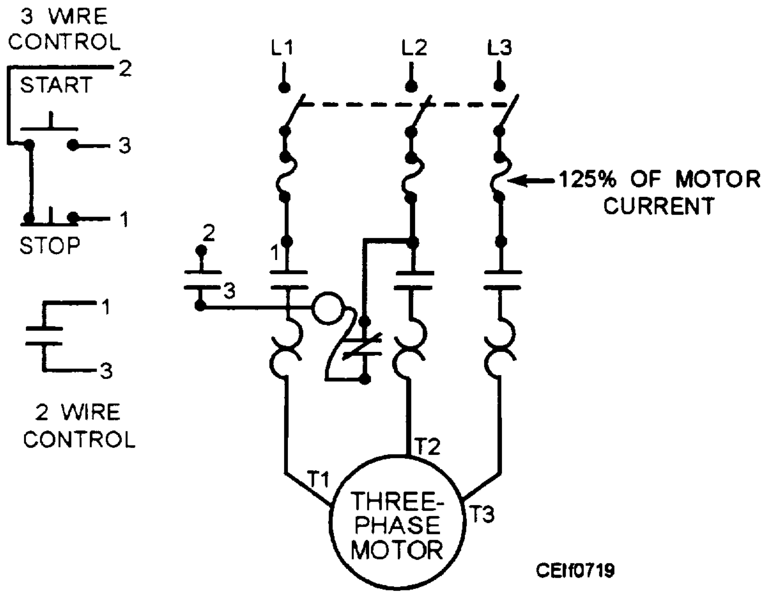

Figure 7-19.—Combination starter with a disconnect switch.

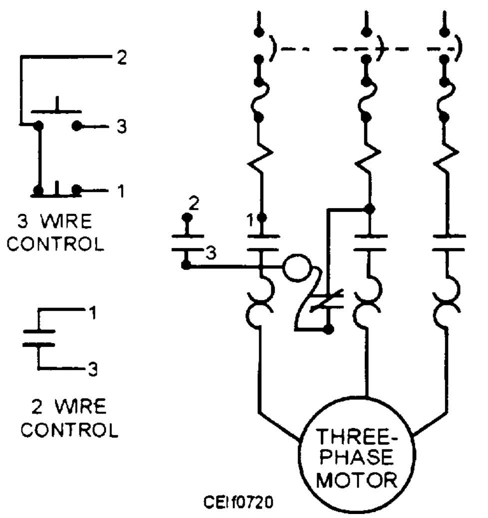

Figure 7-20.—Combination starter with a thermal-magnetic circuit breaker.

START-STOP STATION WITH A PILOT LIGHT

Sometimes it is advisable to have a pilot light on the push-button station to indicate whether the motor is running. The lamp usually is mounted on the station and is connected across the holding coil. Such a connection is shown in figures 7-24 and 7-25. Figure 7-26 shows a control circuit with the pilot light on when the motor is stopped. Normally closed contacts are needed on this starter. When the motor is running, these contacts are open. Contacts are closed when the motor is stopped, and the pilot light goes on.

MOTOR MAINTENANCE

Modern methods of design and construction have made the electric motor one of the least complicated and most dependable forms of machinery in existence and thereby have made the matter of its maintenance one of comparative simplicity. This statement, however, should not be taken to mean that proper maintenance is not important; on the contrary, it must be given careful consideration if the best performance and longest life are to be expected from the motor. The two major features, from the standpoint of their effect upon the general performance of the motor, are those of proper lubrication and the care given to insulation. Lubrication and insulation protect the most vital, and probably the most vulnerable, parts of the machine.

LUBRICATION

The designs of bearings and bearing housings of motors have been remarkably improved. However, this advance in design can cause problems. The bearings of modem motors, whether sleeve, ball, or roller, require infrequent attention. In the case of older designs with housings less tight than on modem machines, oiling and greasing are done frequently. The perpetuation of this habit causes the oiling and greasing of new motors to be overdone. The result is that oil or grease is copiously and frequently applied to the out-side, as well as the inside, of bearing housings. Some excess lubricant is carried into the machine and lodges on the windings where it catches dirt and thereby hastens the ultimate failure of the insulation.

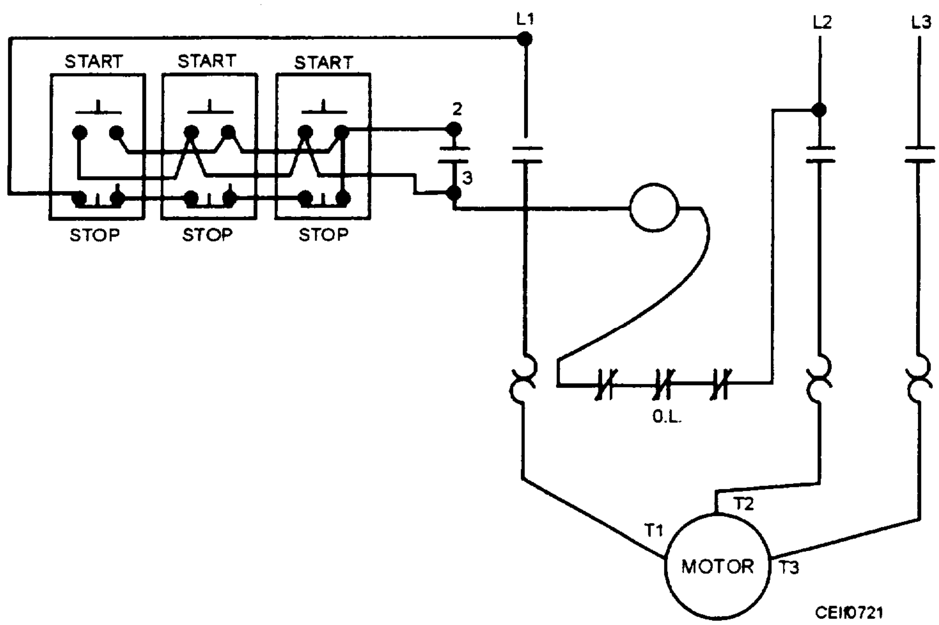

Figure 7-21.—Magnetic switch controlled by three start-stop stations.

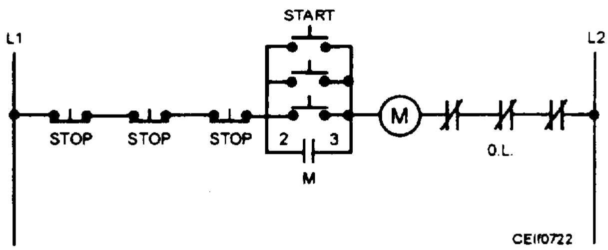

Figure 7-22.—Control circuit for three start-stop stations.

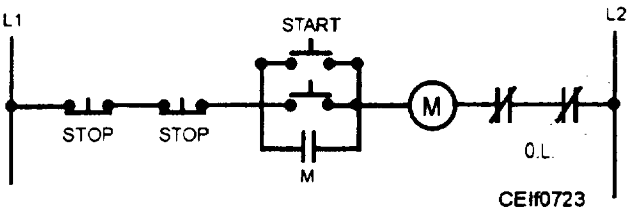

Figure 7-23.—Control circuit for two start-stop stations.

Greasing Ball Bearings

Only a high grade of grease with the following general characteristics should be used for ball-bearing lubrication:

1. Consistency, a little stiffer than that of petroleum jelly, maintained over the operating temperature range
2. Melting point preferably over 150°C
3. Freedom from separation of oil and soap under operating and storage conditions
4. Freedom from abrasive matter, acid, and alkali

In greasing a motor, you must take care not to add too much grease. Overgreasing will cause too high an operating temperature with resulting expansion and leaking of the grease, especially with large bearings operated at slow speeds.

CAUTION

Always review the Material Safety Data Sheet (MSDS) for greases, oils, lubricants, and other hazardous materials before use. Avoid prolonged skin contact with lubricants. Dispose of waste materials in an environmentally responsible manner.

Pressure-Relief Systems

The following procedures are recommended for greasing ball-bearing motors equipped with a pressure-relief greasing system.

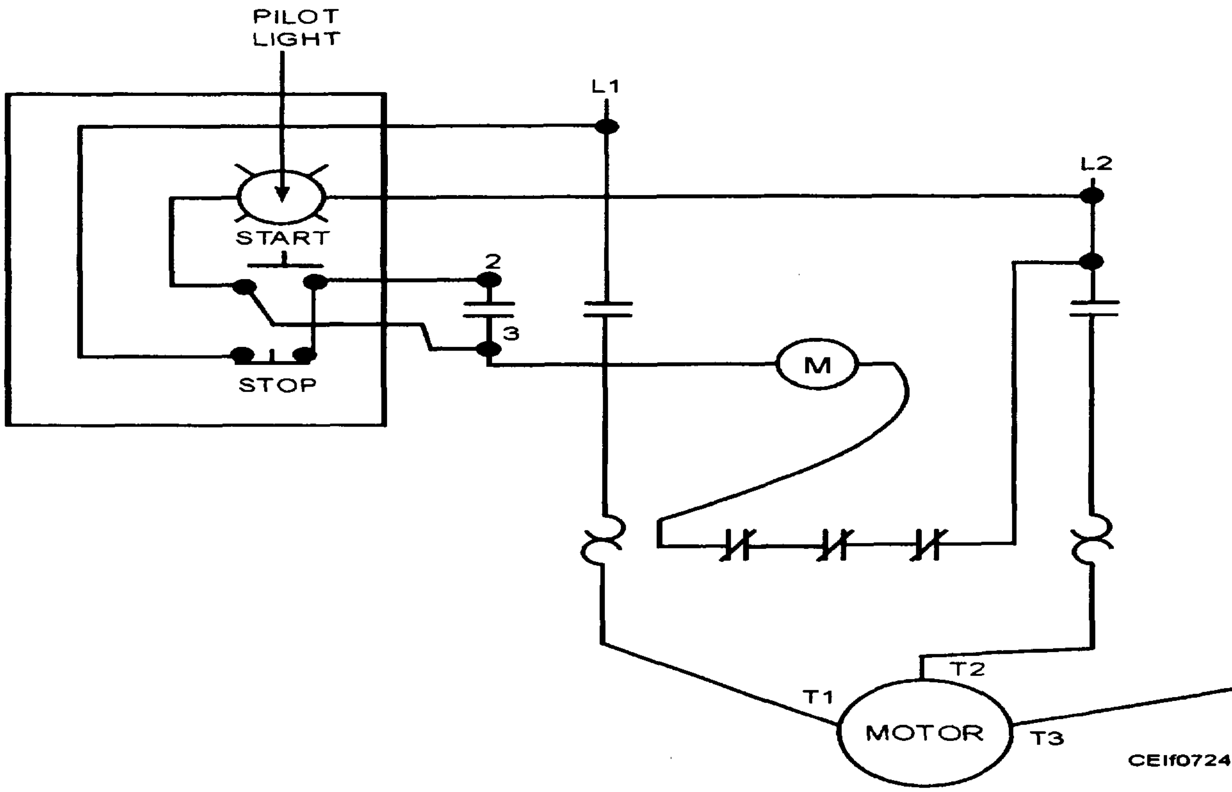

Figure 7-24.—Push-button station with a pilot light.

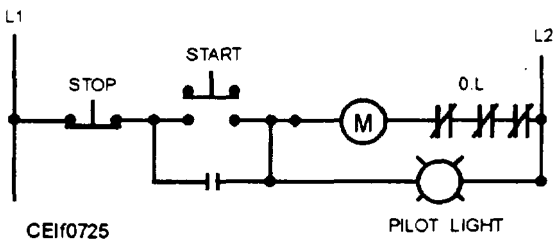

Figure 7-25.—Control circuit with a pilot light.

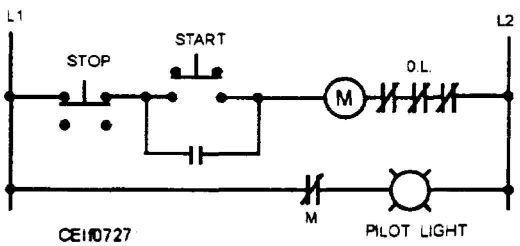

Figure 7-26.—Pilot light indicates when motor is not running.

Before pumping grease into the grease fitting, wipe it clean to prevent the grease from carrying dirt into the fitting and bearing housing. Always remove the relief plug from the bottom of the bearing before using the grease gun. This action prevents applying excessive pressure, which could rupture the bearing seals inside the bearing housing.

With a clean screwdriver or similar tool, free the relief hole of any hardened grease so that any excess grease will run freely from the bearing. With the motor running, add grease with a hand-operated pressure gun until it begins to flow from the relief hole. This procedure tends to purge the housing of old grease.

WARNING

It might prove dangerous to lubricate the motor while it is running; follow the procedures with the motor at a standstill.

After adding the grease, allow the motor to run long enough to permit the rotating parts of the bearing to expel all excess grease from the housing. This very important step prevents overgreasing of the bearing. Stop the motor and tightly replace the relief plug with a wrench.

Motors that are not equipped with the pressure-gun fitting and the relief plug on the bearing housing cannot be greased by the procedures described. Under average operating conditions, the factory-packed grease in the bearing housings of these motors is sufficient to last approximately 1 year. When the first year of service has elapsed and once a year thereafter (or more often if conditions warrant), you should remove the old grease and lubricate the bearings with new grease. To do this. disassemble the bearing housings and clean the inside of the housings and housing plates or caps and the bearings with a suitable solvent. When you have thoroughly cleansed them of old grease. reassemble all parts except the outer plates or caps. Apply new grease, either by hand or from a tube, over and between the balls. The amount of grease you should use varies with the type and frame size of the particular motor. You should consult the instruction sheet that accompanied the motor for this information.

You should add enough grease to fill the bearing housing one-third to one-half full. Do not use more than the amount specified. After reassembling the motor, you should refill any V-grooves that are found in the housing lip with grease (preferably a fibrous. high-temperature-sealing grease) that will act as an additional protective seal against the entrance of dirt or foreign particles.

Roller Bearings

The technique for greasing motors equipped with roller bearings is quite similar to that used for ball bearings. However, you should follow specific instructions for the individual design because more frequent greasing or slight changes in technique may sometimes be necessary.

Sleeve Bearings

With the motor stopped, you periodically should check the oil level in the sleeve-bearing housings. If the motor is equipped with an oil-filler gauge, the gauge should be approximately three-quarters full at all times.

If the oil is dirty. drain it off by removing the drain plug, which is usually located in the bottom or side of the bearing housing. Then flush the bearing with clean oil until the outcoming oil is clean.

Fractional-Horsepower Motors

In fractional-horsepower motors, there may be no means of checking the oil level, as all the oil may be held in the waste packing. In such cases, a good general rule for normal motor service is to add 30 to 70 drops of oil at the end of the first year and to reoil at the end of each subsequent 1,000 hours of motor operation.

Most fractional-horsepower motors built today require lubrication once a year. Small fan and agitator motors often require more frequent lubrication with 3-month intervals between oilings.

MOTOR STORAGE

Motors should be stored in a dry, clean place until ready for installation. Heat should be supplied, especially for larger high-voltage machines, to protect them against alternate freezing and thawing. This advice is equally applicable to spare coils.

Motors that have been in transit in a moist atmosphere or have been idle for an extended period without heat to prevent the accumulation of moisture should be dried out thoroughly before being placed in service. Machines also may become wet by accident. or they may sweat as a result of a difference between their temperature and that of the surrounding air. This condition is harmful particularly in the case of large or important motors, and should be prevented, by keeping them slightly warm at all times.

You can pass current at a low voltage through the windings, use electric heaters, or even use steam pipes for protective purposes. During extended idle periods, you can stretch tarpaulins over the motor and place a small heater inside to maintain the proper temperature.

If a motor should become wet from any cause, you should dry it out thoroughly before operating it again. The most effective method is to pass current through the windings, using a voltage low enough to be safe for the winding in its moist condition.

You can apply heat externally by placing heating units around or in the machine and cover the machine with canvas or some other covering, and then leave a vent at the top to permit the escape of moisture. You can use small fans to help circulation. You should not allow the temperature of the windings to exceed 100°C for Class A insulated motors.

PERIODIC INSPECTION

A systematic and periodic inspection of motors is necessary to ensure best operation. Of course, some machines are installed where conditions are ideal; and dust, dirt, and moisture are not present to an appreciable degree. Most motors, however, are located where some sort of dirt accumulates in the windings, lowering the insulation resistance and cutting down creepage distance. Dusts are highly abrasive and actually cut the insulation while being carried by ventilating air. Fine cast-iron dust quickly penetrates most insulating materials; hence, you can see why motors should be cleaned periodically. If conditions are extremely severe, open motors might require a certain amount of cleaning each day. For less severe conditions. weekly inspection and partial cleaning are desirable. Most machines require a complete overhauling and thorough cleaning out once a year.

BRUSH INSPECTION

Essential for satisfactory operation of brushes is free movement of the brushes in their holders. Uniform brush pressure is necessary to assure equal current distribution. Adjustment of brush holders should be set so that the face of the holder is approximately one eighth of an inch up from the commutator; any distance greater than this will cause brushes to wedge, resulting in chattering and excessive sparking.

Check the brushes to make sure that they will not wear down too far before the next inspection. Keep an extra set of brushes available so that replacements can be made when needed. Sand in new brushes, and run the motor without a load to seat the brushes.

Make sure that each brush surface in contact with the commutator has the polished finish that indicates good contact and that the polish covers all contact surfaces of the brush. Check the freedom of motion of each brush in the brush holder. When replacing a brush, be sure to put it in the same brush holder and in its original position. It will be easier for you to replace the brush properly if you scratch a mark on one side of the brush before you remove it.

Check the springs that hold the brushes against the commutator. Improper spring pressure may lead to commutator wear and excessive sparking. Excessive heating may have annealed the springs, in which case you should replace them and correct the cause of overheating.

COMMUTATOR INSPECTION

Inspect the commutator for color and condition. The part where the brushes ride should be clean and smooth and should be a polished brown color. A bluish color indicates overheating of the commutator.

You should remove any roughness on the commutator by sandpapering or stoning. Never use an emery cloth or an emery stone. For this operation, run the motor without load. If you use sandpaper, wrap it partly around a wooden block. The stone is essentially a piece of grindstone, known to the trade as a commutator stone. With the motor running without load, press the stone or sandpaper against the commutator with moderate pressure and move it back and forth across the commutator surface. If the armature is very rough, it should be taken out and the commutator turned down in a lathe.

WARNING

Use care not to come into contact with moving parts.

RECORDS

The electrical shop should have a record card for every motor. As a minimum, the information on the card should include inspections, repair work, age, and replacement stock number.

CLEANING

About once a year or more often if conditions warrant, motors should be cleaned thoroughly. Smaller motors, the windings of which are not easily accessible, should be taken apart.

First, remove the heavy dirt and grease with a heavy, stiff brush; wooden or fiber scrapers; and cloths. You can use rifle-cleaning bristle brushes in the air ducts. You can blow-dry dust and dirt off, using dry-compressed air at a moderate pressure, perhaps 25 to 50-psi pressure at the point of application, taking care to blow the dirt out and away from the windings. If the dirt and dust are metallic? conducting, or abrasive, using air pressure is not as satisfactory as using a suction system.

CAUTION

When cleaning motors with compressed air, wear safety goggles and hearing protection. Dispose of lubricants and contaminated materials in an environmentally responsible manner.

You can easily remove grease, oil, and sticky dirt by applying cleaning liquids specifically designed for the purpose. These liquids evaporate quickly and, if not applied too generously, will not soak or injure the insulation. If you do use one of these liquids, be sure to follow the manufacturer’s direction for use.

MOTOR START-UP

After new motors and controls are installed, they should be checked for operation under load for an initial period of at least 1 hour. During this time, the electrician can observe if any unusual noise or hot spots develop. The operating current must be checked against the nameplate ampere rating. This check requires skill in the proper connection, setting, and reading of a clamp-on ammeter. The nameplate ampere reading multiplied by the service factor (if any) sets the limits of the steady current. This value should NOT be exceeded.

Check the power supply against the nameplate values; they should agree. Most motors will operate successfully with the line voltage within 10 percent (plus or minus) of the nameplate value or within 5 percent of the frequency (hertz). Most 220-volt motors can be used on 208-volt network systems but with slightly modified performance. Generally, 230-volt motors should not be used on 208-volt systems.

To reconnect a dual-voltage motor to a desired voltage, follow the instructions on the connection diagram on the nameplate.

Motor-starter-overload-relay heaters of the proper size must be installed. The motor will not run without them. Sizing information is found inside the control enclosure cover. The starting fuses should be checked in a similar manner. The selection of the correct fuse size must be according to the *NEC®* or local requirements.

If the motor has not been installed in a clean, well-ventilated place, clean the area. Good housekeeping, as well as direct accident and fire-prevention techniques, must be emphasized.

Check the motor mounts to be sure that they are secure and on a firm foundation. If necessary, add grout to secure the mounts.

Rotate the end shields to place grease fittings, plugs, or any openings in the best, or most accessible, location. Oil or grease the bearings, if necessary.

EQUIPMENT TROUBLESHOOTING

In troubleshooting motors, the first step is to shut down the machine and lock it out for repair or adjustment. The most valuable troubleshooting asset is your ability to apply common sense when analyzing a control operation. Also, experienced Construction Electricians learn to use sensory functions to diagnose and locate trouble.

- LOOKING may reveal contacts stuck and hung up, thereby creating open circuits.
- LISTENING may indicate loose parts, faulty bearings, excessive speed, and so forth.
- SMELLING may indicate burning insulation or a coil failure.
- TOUCHING may reveal excessive motor shaft play, vibration, or normal heat.

Using this seemingly oversimplified procedure to locate a problem may save you many hours of labor. Consider the length of time it would take to become thoroughly familiar with a complicated schematic diagram, compared with locating a few contacts that are stuck by merely LOOKING.

However, finding a problem in an installation is not usually this easy. An orderly, step-by-step approach is required. Circuit operation is separated into logical parts. Circuits and components are then divided into smaller parts to determine their functions, the relationships to one another, and the effect that they have on each other in the overall control system operation. Each step leads closer to the source of the difficulty, finally pinpointing the problem. This procedure may require the use of a voltage tester, ammeter, multimeter, jumper wires, and other tools.

Check the power supply to see if it is on and if it is correct. Test all protective devices. If a coil does not energize (fig. 7-27), connect a jumper wire from L1 to terminal 3 of the control circuit. By jumping across the contacts of the limit switch and push buttons, you have separated the circuit operation into logical parts. If the starter coil is now energized, the problem may be in the limit switch or STOP or START push buttons. You now can test smaller circuits and components by "jumping" around them individually. Test the limit switch, for example, then go to the control station, if necessary. By an orderly process of elimination accomplished by testing all possible fault areas, you can locate the problem accurately and efficiently.

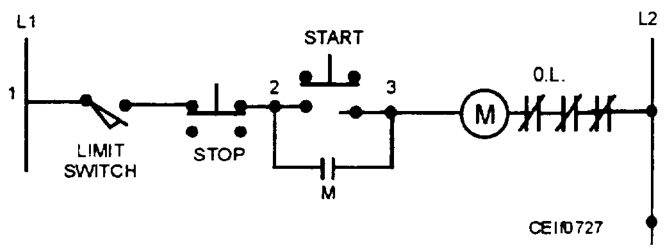

Figure 7-27.—Start-and-hold control circuit.

WARNING

Indiscriminate jumping, however, should not be practiced because of the danger of short circuits. For example, a jumper should never be placed across a power-consuming device, such as a contactor coil; voltage or ohmmeters testers are used in this instance. If an ohm-meter is used to test a coil for continuity, the power must be OFF.

Table 7-2 is provided as an aid to servicing electric control equipment. Refer to the table to find the possible causes of a controller symptom.

Table 7-2.—Controller Troubleshooting Tips

Controller Symptoms	Possible Causes and Recommended Items to Investigate
Arcing and burning of contacts	Should handle very little current and have sealing circuit; misapplied
Bellows distorted (on thermally operated devices)	Mechanical binding; temperature allowed to pass control limits
Blowout coil overheats	Overcurrent; wrong size of coil; loose connections on stud or tip; tip heating; excess frequency
Breakage, distortion and wear	Overheating; mechanical abuse; severe vibration; shock
Breakdown (of static accessories)	High temperature; moisture; overcurrent; overvoltage; corrosive atmosphere; mechanical damage; overload; ac on dc capacitor; continuous voltage on intermittent types
Broken flexible shunt	Large number of operations; improper installation; extreme corrosive conditions; burned from arcing
Broken pole shader	Heavy slamming caused by overvoltage; weak tip pressure; wrong coil; mechanical overload; low frequency
Bulbs distorted (on thermallv operated devices)	Liquid frozen in capillary tube
Burning and welding of control contacts and shunts	Shorts circuits on control circuits with too large protecting fuses; severe vibration; dirt; oxidation
Coil failure	Moisture; overvoltage; high ambient temperature; failure of magnet to seal in on pickup; too rapid duty cycle; metallic dust; corrosive atmosphere; chattering of magnet; wrong coil; holding resistor not cut in; intermittent coil energized continuously; mechanical failure; mechanical overload; mechanical underload; handling fluid above rated temperature
Contact opens prematurely	Dirt in air gap; shim too thick; too much spring and tip pressure; misalignment; not enough capacitance; not enough resistance
Contact takes longer than normal too open	Shim too thin; weak spring and tip pressure; gummy substance on magnet faces; too much capacitance; too much resistance
Contact-tip troubles	
a. Filing or dressing	Do not file silver tips; rough spots or discoloration will not. harm efficiency

Table 7-2.—Controller Troubleshooting Tips—Continued

b. Interrupting excessively high current	Check for grounds, shorts, or excessive motor currents
c. Excessive jogging	Install larger device rated for jogging service
d. Weak tip pressure	Replace contacts and springs; check carrier for damage
e. Dirt on surfaces	Clean contacts; reduce exposure
f. Short circuits or ground fault	Remove fault; be sure fuse/breaker size is correct
g. Loose connection	Clean then tighten
h. Sustained overload	Check for excessive motor current or install larger controller
Corrosion	Excess moisture; salt air; acid fumes
Excess wear or friction	Abrasive dust; high inertia load; excess temperature
Failure to break arc	Too much current; too much voltage (dc); misapplication; too much inductance
Failure to hold load	Worn parts; out of adjustment; misapplication; failure to use recommended substitute parts
Failure to make contact	Mechanical damage; dirt; corrosive; wear allowance gone
Failure to open or close	Low voltage; coil open; mechanical binding; mechanical overload; no voltage; wrong coil: shorted turns; excessive magnet gap: mechanical binding; gummy substance on magnet faces: air gap in magnet destroyed; contact tip welded; voltage not removed; corrosion; scale; dirt; operating above rated pressure; damaged motor
Failure to operate properly	Coils connected wrong; wrong coil; mechanical binding
Failure to release	Improper adjustment; coil not energized; mechanical binding: low voltage or current; coil open; shorted turns
Failure to reset overload relay	Mechanical binding; worn parts; dirt; broken mechanism; corrosion; worn parts; resetting to soon
Failure to set overload relay	Improper adjustment; mechanical binding; coil not de-energized; worn parts
Failure to time out (on motor operated relays)	Mechanical binding; worn parts; motor damaged; no voltage to motor; dirt
Failure to trip (during overload conditions)	Heater incorrectly sized; mechanical binding; relay previously damaged by short circuit current; dirt; corrosion; motor and relay in different ambient temperatures
Fast trip (on overload relays)	High temperature; wrong heaters
Flashover	Jogging; short circuits; handling too large motor; moisture; acid fumes; gases; dirt
Heating	Overcurrent; loose connection; spring clips loose or annealed; oxidation: corrosion

Table 7-2.—Controller Troubleshooting Tips—Continued

High trip	Mechanical binding; wrong or shorted coil; assembled wrong
Insulation failure	Moisture; acid fumes; overheating; accumulation of dirt on surfaces; voltage surges; short circuits; mechanical damage; overvoltage
Leaks and mechanical failure (on pneumatic and hydraulic controllers)	Corrosion; mechanical damage; excessive pressure; worn seat; solid matter in seat/strainer
Low trip	Wrong coil; assembled wrong
Mechanical wear or failure	Abrasive dust and dirt; misapplication; mechanical damage; excessive operating speed
Noisy magnet	Broken pole shader; magnet faces not true as result of wear or mounting strains; dirt on magnet faces; low voltage; mechanical overload; improper adjustment (too much pressure or incorrect lever ratio)
Overheating	Incorrect heat rating; running on starter resistor; overload; overvoltage; intermittent-rating device operating too long
Pitted, worn, or broken arc-chutes	Abnormal interrupting duty; excessive vibration or shock; moisture; improper assembly; rough handling
Premature blowing of protective fuses	Extra heating from outside; copper oxide on ferrules and clips; high ambient temperature
Resistor failure (on static accessories)	Overcurrent; moisture; corrosive atmospheres
Short contact life	Jogging; handling abnormal currents; lack of lubrication where recommended; abrasive dirt
Slow trip (of overload relays)	Mechanical binding; dirt; low temperature; wrong heaters
Sticking	Dirt; worn parts; improper adjustment; corrosion; mechanical binding
Too slow blowing (of fuse)	Wrong size fuse for application
Trips too low (on overload relay)	Wrong heater; relay in high ambient temperature (motor)
Various mechanical failures	Overvoltage; heavy slamming; chattering; abrasive dust; underload
Wear on magnet	Overvoltage; broken pole shader; wrong coil; underload; weak tip pressure; chattering; load out of alignment
Wear on segments or shoes (of a rheostat)	Abrasive dust; very heavy duty; no lubrication